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(71)Applicant : SEIKO INSTRUMENTS INC

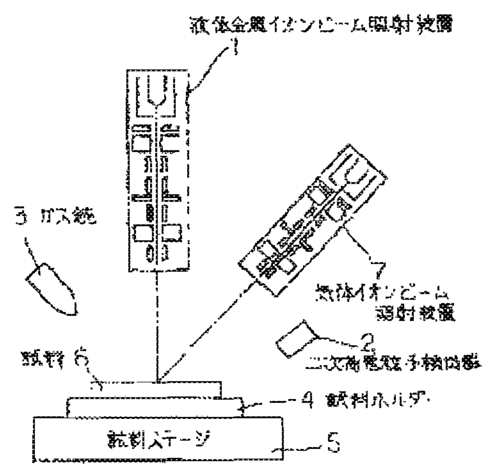
(72)Inventor : KODAMA TOSHIO
KADA MASAKATSU
FUJII TOSHIAKI
IWASAKI KOJI
SUGIYAMA YASUHIKO
TAKAGI YASUYUKI

(54) ION BEAM DEVICE, AND WORKING METHOD OF THE SAME

(57)Abstract:

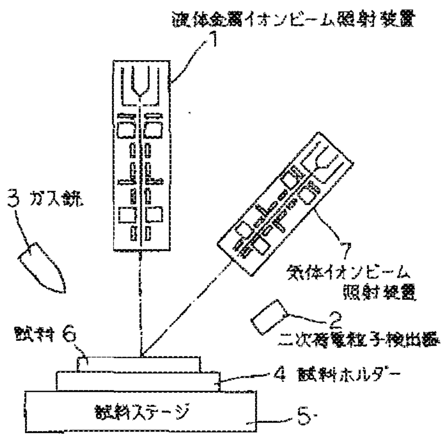
PROBLEM TO BE SOLVED: To provide an ion beam device capable of preventing secondary particles from re-adhesion on an observing surface (cross section).

SOLUTION: The ion beam device comprises a liquid metal ion beam irradiation device 1 forming a cross section by irradiating a prescribed liquid metal ion beam on a specified site of a specimen 6, and a gaseous ion beam irradiation device 7 removing a damaged layer on a prescribed region by scanning the prescribed region (observing region) of the cross section by the gaseous ion beam converged into a prescribed beam radius.

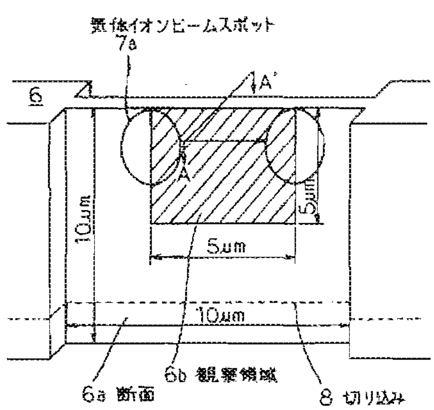


DRAWINGS

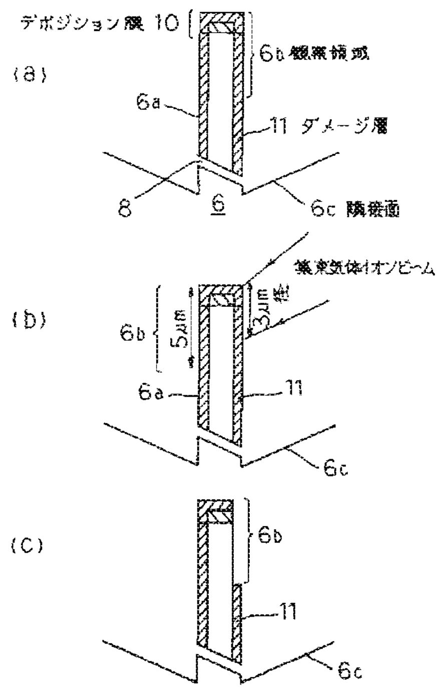
[Drawing 1]



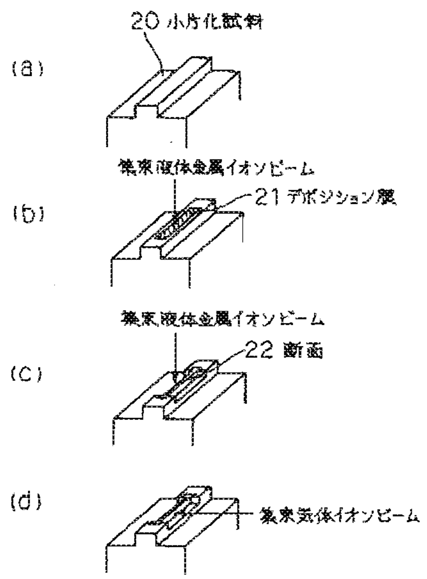
[Drawing 2]



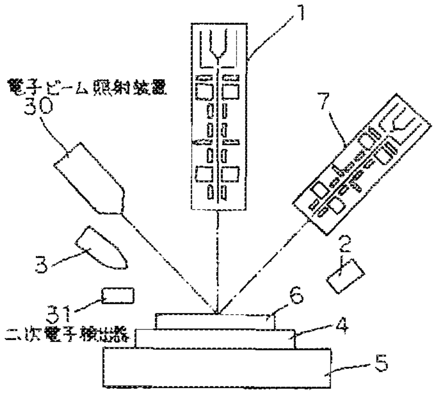
[Drawing 3]



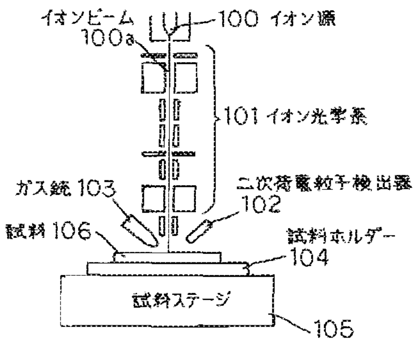
[Drawing 4]



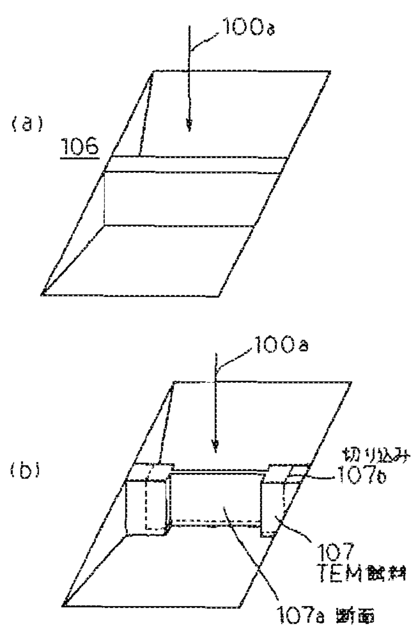
[Drawing 5]



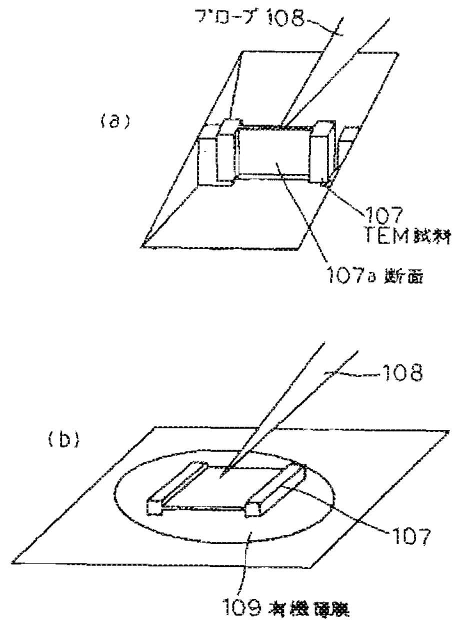
[Drawing 6]



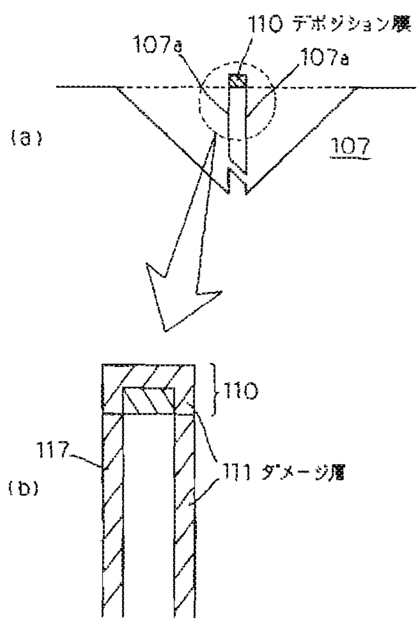
[Drawing 7]



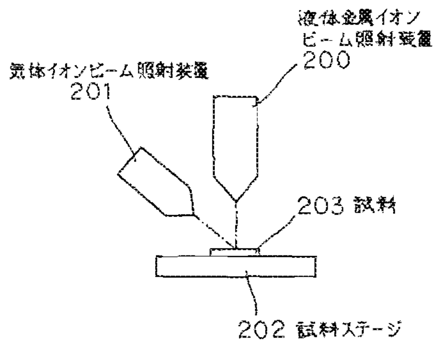
[Drawing 8]



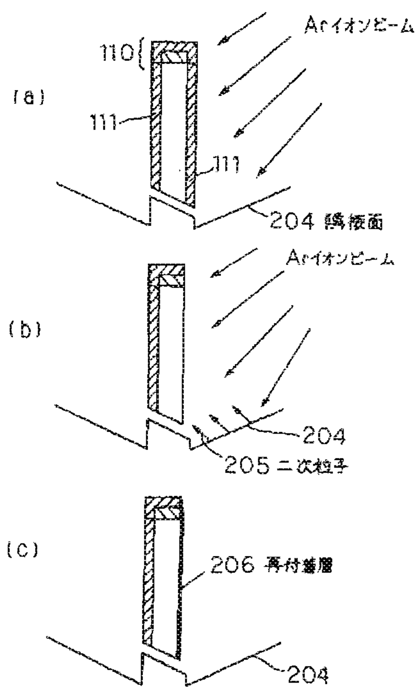
[Drawing 9]



[Drawing 10]



[Drawing 11]



[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]
This invention relates to the ion beam equipment and the ion beam machining method of processing it by irradiating the specific site of a sample with an ion beam.
[0002]
[Description of the Prior Art]
As ion beam equipment, the focused ion beam (FIB:Focused Ion Beam) device and the ion milling system are known. These devices are used for sample production at the time of carrying out section observation of the deficit part of a wafer, for example by TEM (Transmission Electron Microscope), SEM (Scanning Electron Microscope), etc. Since the cross section processing of the specific sites, such as a defect, can be carried out correctly, scanning a specimen surface, detecting the secondary electron by which it is generated at the time of this scan, and observing as a picture by the ion beam which fully converged, especially the FIB device is widely used as an evaluation system of a semiconductor manufacturing process.

[0003]
The outline composition of the conventional FIB device is shown in drawing 6. The principal part of this FIB device consists of the ion source 100, the ion optics system 101, the secondary charged particle detector 102, the tear gas gun 103, the sample electrode holder 104, and the sample stage 105.
[0004]
The ion source 100 is a liquid metal ion source represented by gallium (Ga), for example. It is for making it scan on the sample 106, while the ion optics system 101 converges the ion beam from the ion source 100, Condensing lens (electrostatic lens), beam BURANKA, movable diaphragm, and 8 pole SUTIGU meter, an object lens (electrostatic lens), a scanning electrode, etc. are arranged sequentially from the ion source 100 side. The secondary charged particle detector 102 is what detects the secondary charged particle generated when the focused ion beam (it is only hereafter described as FIB.) 100a is scanned on the sample 106, The observation images (SIM image) by a scanning ion microscope (SIM:Scanning Ion Microscope) can be obtained by performing image processing based on this detection result.
[0005]
The sample stage 105 is a stage in which five five axis controls are possible. In five five axis controls, three-

dimensional movement in the XYZ direction, rotation of the circumference of an axis (Z-axis) vertical to an XY plane, and control of a tilt are performed. The sample electrode holder 104 is because the sample 106 is fixed, is laid on the movable carriage (un-illustrating) called a boat, and is carried in to up to the sample stage 105. The sample 106 is a wafer, for example. The tear gas gun 103 sprays the predetermined gas for forming the deposition film as a protective film in the surface of the sample 106.

[0006]

Next, the concrete sample production procedures using an above-mentioned FIB device are explained. A series of production procedures of the TEM sample by the technique called the taking-up method (or the liftout method) to (a) of drawing 7 and (b) are shown typically. Hereafter, the production procedures of a TEM sample are explained with reference to drawing 6 and drawing 7.

[0007]

First, the wafer which is the sample 106 is fixed on the sample stage 105, and based on the position information on the deficit part given beforehand, near alignment is performed so that FIB100a from the ion source 100 may be irradiated near the deficit part. then, the neighborhood of a deficit part is scanned by FIB100a, and the position of a deficit part is pinpointed, looking at the SIM image acquired by this scan (carrying out position appearance). while carrying out position appearance and the back's spraying predetermined gas on the surface of a wafer by the tear gas gun 103, a deposition film (protective film) is formed by scanning the predetermined range which includes the deficit part of the surface of a wafer by FIB100a. Generally formation of this deposition film is called ion assistant deposition (or ion beam CVD (Chemical VaporDeposition)).

A deposition film can be selectively formed in the portion with which it irradiated by FIB100a.

[0008]

Then, as shown in drawing 7 (a), it irradiates with the neighborhood of a deficit part of the surface of a wafer by FIB100a, is processed roughly, and finish-machines by irradiating the machining part with FIB100a further. In this processing, since FIB100a is irradiated from a normal line direction to the surface of a wafer, the surface can delete to **** the field where FIB was irradiated, and the section 107a as eventually shown in drawing 7 (b) is obtained. Whether thickness which looked at the section 107a section from the upper part is made to what extent thin changes with the construction material of a sample, and accelerating voltage of TEM to be used. For example, Si system semiconductor sample needs to be 0.1 micrometer or less, to observe a lattice image by TEM with an accelerating voltage of 200 kV. When conducting 3D analysis etc. by the tomography by TEM, about 0.5 micrometer is made to the thickness of a sample.

[0009]

After adjusting the degree of incidence angle to the wafer of FIB100a by controlling the tilt angle of the sample stage 105 finally, by processing by FIB100a. The slitting 107b (portion shown with the dashed line in drawing 7 (b)) as shown in drawing 7 (b) around the portion in which the section 107a was formed is formed. The portion which is taken out along with this slitting 107b and including the section 107a serves as TEM sample 107.

[0010]

A dedicated device (manipulator) is used in extraction of TEM sample 107. An example of extraction of the TEM sample by the taking-up method is shown in (a) of drawing 8, and (b).

[0011]
First, the tip of the probe 108 which consists of glass materials is brought close to the section 107a of one side of TEM sample 107 produced in the procedure of drawing 7. If the tip of the probe 108 approaches the section 107a to some extent, as shown in drawing 8 (a), TEM sample 107 will adsorb at the tip of the probe 108 with static electricity. And it moves onto the organic thin film 109 which has the adhesiveness independently prepared in the probe 108 while it had been in the state to which TEM sample 107 stuck at the tip, and as shown in drawing 8 (b), TEM sample 107 which adsorbed at the tip is placed on the organic thin film 109. The adhesiveness of the organic thin film 109 is fixed and TEM sample 107 separates from the tip of the probe 108.
[0012]
The organic thin film 109 in which TEM sample 107 was fixed as mentioned above is carried in to a TEM device other than a FIB device, and the section 107a of TEM sample 107 is observed there. These days, the compounded type FIB device which built viewing devices, manipulators, etc., such as a scanning electron microscope and energy dispersive X-ray spectrometer, into the FIB device is also provided, and one FIB device can perform observation now from sample production.
[0013]
There is also the technique of breaking a wafer with a dicing saw besides the production techniques of the TEM sample by the taking-up method explained above, producing the wafer-ized sample of a specified part, and producing a TEM sample by fixing this wafer-ized sample to an exclusive sample electrode holder, and carrying out cross section processing by FIB.
[0014]
However, also in which technique of sample production mentioned above, the damage by FIB is received in a processed surface (section) in the case of the cross section processing by FIB. Drawing 9 (a) is a sectional view of the portion of TEM sample 107 of drawing 7 (b), and drawing 9 (b) is the elements on larger scale. The deposition film 110 is a protective film formed at the time of the cross section processing by FIB among drawing 9.
[0015]
In the cross section processing by FIB, while receiving the damage by FIB in the surface of the section 107a of TEM sample 107, some ion (for example, Ga ion) contained in FIB is poured in, and the damaged layer (crushing layer) 111 as shown in drawing 9 (b) is formed. The element contained in the sample itself from the first and the poured-in ion (Ga) will be intermingled [amorphous] by the damaged layer 111. If the unnecessary damaged layer 111 is formed in a field (section 107a) to observe in this way, the damaged layer 111 serves as hindrance, and the good TEM observation, especially a clear lattice image, cannot be observed. The problem of such a damaged layer is similarly produced in SEM sample production.
[0016]
Then, the technique etching (ion milling) using the ion beam of low energy, for example, an argon (Ar) ion beam, removes a damaged layer is proposed. For example, the FIB device with which the Io milling device was built into the gazette of the patent No. (JP,6-260129,A) 3117836 and which can remove a damaged layer is indicated.
[0017]
Drawing 10 is a mimetic diagram showing the outline composition of the FIB device indicated in the above-

mentioned gazette. The principal part of this FIB device consists of the liquid metal ion-beam-irradiation device 200, the gas ion beam irradiation unit 201, and the sample stage 202.

[0018]

The liquid metal ion-beam-irradiation device 200 can be provided with an ion optics system as shown in drawing 6, and can scan the predetermined portion of the surface of the sample 203 laid on the sample stage 202 by the ion beam (FIB) which was pulled out from the liquid metal ion source and fully converged. A liquid metal ion source is a source of Ga ion, for example.

[0019]

The gas ion beam irradiation unit 201 irradiates with the field of the predetermined range containing the portion by which cross section processing was carried out by the gas ion beam pulled out from the source of gas ion uniformly. As a source of gas ion, there is an Ar ion source, for example. Since it is not necessary to converge a gas ion beam like FIB, the ion optics system which fully converges an ion beam with which the liquid metal ion-beam-irradiation device 200 is equipped on the gas ion beam irradiation unit 201 is not provided. Since an ion optics system which fully converges an ion beam is dramatically expensive, it has realized low cost-ization by not using this.

[0020]

In the above-mentioned FIB device, cross section processing of the sample 203 is first carried out by FIB from the liquid metal ion-beam-irradiation device 200. A damaged layer as shown in drawing 9 (b) on the occasion of this cross section processing is formed in a section. After cross section processing, the field containing a cross section processing portion is uniformly irradiated with the gas ion beam from the gas ion beam irradiation unit 201, and etching removal of the damaged layer on a section is carried out.

[0021]

The quantity is small although a section receives a damage also by the exposure of a gas ion beam. To the thickness of the damaged layer in the case of a liquid metal ion beam being 20-30 nm, since the thickness of the damaged layer in the case of a gas ion beam is about several nanometers, the damaged layer does not become a problem by the section observation in TEM or SEM.

[0022]

[Problem(s) to be Solved by the Invention]

Since a damaged layer is made in the processed section when cross section processing of the sample is carried out by FIB as mentioned above, there is a problem that good section observation cannot be performed in TEM, SEM, etc.

[0023]

Although the above-mentioned problem is solved by removing a damaged layer by a gas ion beam after the cross section processing by FIB, the new problem of the reattachment of the aggregated particle by the exposure of a gas ion beam which is explained below arises in this case.

[0024]

The process in which an aggregated particle carries out the reattachment to (a) - (c) of drawing 11 is shown typically. As shown in drawing 11 (a), in order to remove the damaged layer 111 formed in the section, Ar ion beam is irradiated. The irradiation area of this Ar ion beam includes a section and the contact surface 204 which adjoins this. If Ar ion beam is irradiated by the contact surface 204, as shown in drawing 11 (b), the aggregated particle 205 will be emitted from the contact surface 204. The aggregated particle 205

emitted from this contact surface 204 adheres to the section after the damaged layer 111 was removed, and the reattachment layer 206 as shown in drawing 11 (c) is formed. The reattachment layer 206 has an unknown ingredient and bars good section observation.
[0025]
The purpose of this invention is to provide the ion beam equipment and the ion beam machining method of being able to solve each of above-mentioned problems and preventing the reattachment of the aggregated particle to an observed face (section).
[0026]
[Means for Solving the Problem]
This invention is characterized by ion beam equipment comprising the following to achieve the above objects.
A liquid metal ion-beam-irradiation means to irradiate a specific site of a sample with a predetermined liquid metal ion beam, and to form a section in it.
A gas ion beam irradiation means which scans a predetermined field of said section by a gas ion beam which converged on a predetermined beam diameter, and removes a damaged layer on a field predetermined [this].

[0027]
This invention is characterized by an ion beam machining method comprising the following.
The 1st process of irradiating a specific site of a sample with a predetermined liquid metal ion beam, and forming a section in it.
The 2nd process of scanning a predetermined field of said section by a gas ion beam which converged on a predetermined beam diameter, and removing a damaged layer on a field predetermined [this].

[0028]
A predetermined field of a section formed by irradiating with a predetermined liquid metal ion beam in this invention as above-mentioned, A damaged layer on the field is removed by scanning an observation area where SEM observation or TEM observation is specifically performed by a gas ion beam which converged on a predetermined beam diameter. Although a wall surface and the bottom adjoin a section, these contact surfaces do not adjoin an observation area. It is possible to limit an irradiation area of a gas ion beam to an observation area by having converged a gas ion beam on a predetermined beam diameter. Since it is such, in this invention, a gas ion beam is fundamentally irradiated by only observation area, and it does not glare to a contact surface (a wall surface and the bottom). Therefore, like before, a gas ion beam is irradiated by contact surface, an aggregated particle is emitted, and it has not been said that this emitted aggregated particle carries out the reattachment to an observation area where a damaged layer was removed, and poses a problem.
[0029]
[Embodiment of the Invention]
Next, the embodiment of this invention is described with reference to drawings.
[0030]
The main composition of the FIB device which is one embodiment of this invention is typically shown in

drawing 1. This FIB device consists of the liquid metal ion-beam-irradiation device 1, the secondary charged particle detector 2, the tear gas gun 3, the sample electrode holder 4 that fixes the sample 6, the sample stage 5, and the gas ion beam irradiation unit 7.

[0031]

The liquid metal ion-beam-irradiation device 1 is the existing device provided with a liquid metal ion source and the ion optics system for making the liquid metal ion beam pulled out from this liquid metal ion source scan on the sample 6, while fully converging. An ion optics system is the same as that of the ion optics system 101 which **6**(ed), and condensing lens (electrostatic lens), beam BURANKA, movable diaphragm, and 8 pole SUTIGU meter, an object lens (electrostatic lens), a scanning electrode, etc. are arranged one by one from the liquid metal ion source side. As liquid metal ionic species, gallium (Ga) can be used, for example.

[0032]

The gas ion beam irradiation unit 7 is provided with the following.

The source of gas ion.

The ion optics system for making the gas ion beam pulled out from this source of gas ion scan on the sample 6, while fully converging.

An ion optics system is a thing of the almost same composition as the ion optics system used for the above-mentioned liquid metal ion-beam-irradiation device 1. As a gas ion kind, there are argon, oxygen, helium, neon, a xenon, krypton, radon, etc. The optic axis of the gas ion beam irradiation unit 7 crosses at the optic axis and position of the liquid metal ion-beam-irradiation device 1.

[0033]

The tear gas gun 3, the sample electrode holder 4, and the sample stage 5 are the same as what was shown in drawing 6. The secondary charged particle detector 2 detects the secondary charged particle generated when the sample 6 is irradiated with a liquid metal ion beam and a gas ion beam. By performing image processing based on this detection result, the SIM image in each at the time of the etching processing by a liquid metal ion beam and the etching removal by a gas ion beam is acquired.

[0034]

Next, sample production using the FIB device of this embodiment is explained concretely. By the following explanation, two, the production procedures of the TEM sample by the taking-up method and the production procedure of the TEM sample from the wafer-ized sample produced by the dicing saw, are mentioned as an example, and they are explained concretely.

[0035]

(1) Production procedure of the TEM sample by the taking-up method :

First, the neighborhood of the specified part (deficit part) of the wafer which is the sample 6 in the liquid metal ion beam which converged from the liquid metal ion-beam-irradiation device 1 is scanned, and a section is formed (cross section processing). Since this cross section processing is fundamentally [as the procedure shown in (a) of drawing 7, and (b)] the same, that detailed explanation is omitted here.

[0036]

The predetermined field (observation area) of the section of the sample 6 is scanned after cross section processing (processing of drawing 7 (b)) by the gas ion beam which converged from the gas ion beam irradiation unit 7, and the damaged layer (un-illustrating) on the predetermined field is removed. The

exposure of the section by a gas ion beam is typically shown in drawing 2.

[0037]

In drawing 2, the section 6a is the portion which processed the specified part of the wafer which is the sample 6 by the liquid metal ion beam which converged from the liquid metal ion-beam-irradiation device 1, and the size is 10 micrometers (length (depth)) x 10 micrometers (width). The observation area 6b (slash part shown with the dashed line) located in the center of this section is a field where TEM observation is performed, and that size is 5 micrometers (length (depth)) x 5 micrometers (width). The slitting 8 (dashed line) corresponding to [cut deeply and] 107b shown by drawing 7 (b) is formed in the lower part (pars basilaris ossis occipitalis) of the section 6a, and the portion divided by this slitting 8 is taken out as a TEM sample.

[0038]

The gas ion beam which converged from the gas ion beam irradiation unit 7 enters aslant to the section 6a, and the size of the beam spot 7a is smaller than the size of the section 6a, and smaller than the size of the observation area 6b more desirably. As for the beam diameter (given with the half breadth in Gaussian distribution) on the section 6a of the gas ion beam which converged, specifically, when the sizes of the observation area 6b are 5 micrometers (length (depth)) x 5 micrometers (width), about 3 micrometers in diameter are desirable. By scanning the observation area 6b by this beam spot 7a, the damaged layer on the observation area 6b is removed.

[0039]

The removal process of the damaged layer by the gas ion beam which converged on (a) - (c) of drawing 3 is shown typically. (a) - (c) of drawing 3 corresponds to the A-A' sectional view of the section 6a shown in drawing 2.

[0040]

The deposition film 10 is a protective film formed when performing cross section processing by the liquid metal ion beam which converged from the liquid metal ion-beam-irradiation device 1 among drawing 3 (a). The damaged layer 11 is formed on the section 6a, and etching removal of the portion on the observation area 6b of this damaged layer 11 is scanned and carried out by the gas ion beam (beam diameter of 3 micrometers) which converged from the gas ion beam irradiation unit 7 (refer to (b) and (c) of drawing 3). Same processing is performed also to the field of an opposite hand. The exposure of the gas ion beam to the field of an opposite hand can be performed by rotating 180 degrees of sample stages 5.

[0041]

In the above-mentioned etching removal, in order to irradiate only with the observation area 6b by the gas ion beam which converged and to remove the damaged layer 11, when removing the damaged layer 11, a gas ion beam is not irradiated by the contact surface 6c contiguous to the section 6a. For this reason, in the contact surface 6c, discharge of the aggregated particle by the exposure of a gas ion beam like before is not produced. Therefore, the reattachment layer by the aggregated particle from the contact surface 6c like before is not formed in the field of the observation area 6b where the damaged layer 11 was removed.

[0042]

Cross section processing is performed as mentioned above, it is the same technique as extraction of the TEM sample by the probe shown in (a) of drawing 8 and (b), the TEM sample part from which the damaged layer was removed is taken out from a wafer, and adhesive fixing is carried out to an organic nature thin film.

[0043]
Although the example of drawing 3 showed only the contact surface 6c located in the lower part (pars basilaris ossis occipitalis) of the section 6a as a contact surface, as shown in drawing 2, a contact surface exists also in the both sides of the section 6a in practice. According to this embodiment, a gas ion beam is not irradiated by these contact surfaces when removing the damaged layer by a gas ion beam, either.
[0044]
It may be made to fix the taken-out TEM sample part to a sample electrode holder for exclusive use, without carrying out adhesive fixing to an organic nature thin film. In this case, the rework of a TEM sample part becomes possible.
[0045]
If the spot size on the section 6a of the gas ion beam which converged is set as bigger size (however, smaller than the section 6a), a damaged layer is more removable in a short time. although a part of gas ion beam is irradiated by the contact surface and an aggregated particle is emitted in this case, that burst size is markedly boiled compared with the burst size of the aggregated particle in the former, and there is. [few] Therefore, even if a reattachment layer is formed in the observation area where the damaged layer was removed, the quantity (thickness) comes out very only, and, for a certain reason, section observation is not barred.
[0046]
(2) Production procedure of the TEM sample from a wafer-ized sample :
The production processes of the TEM sample from a wafer-ized sample are typically shown in (a) - (c) of drawing 4.
[0047]
A portion including the specified part (deficit part) of the wafer which is the sample 6 is started with a dicing saw, a preliminary processing process is performed, and sectional shape as shown in drawing 4 (a) produces the wafer-ized sample 20 of a convex configuration. The field of the heights of the wafer-ized sample 20 is the surface of a wafer, and calls the field of these heights the surface of the wafer-ized sample 20 in subsequent explanation.
[0048]
The wafer-ized sample 20 is held to the existing attachment component, clamp immobilization is carried out and this is carried in to the sample electrode holder 4 on the sample stage 5. The position of the sample stage 5 and a tilt angle are adjusted so that the liquid metal ion beam which converged from the liquid metal ion-beam-irradiation device 1 may enter into an abbreviated perpendicular to the surface of the wafer-ized sample 20 on the sample stage 5.
[0049]
Then, while spraying predetermined gas on the surface of the wafer-ized sample 20 using the tear gas gun 3, the deposition film (protective film) 21 as shown in drawing 4 (b) is formed by scanning the range which includes the processing area of the surface of the wafer-ized sample 20 by the liquid metal ion beam which converged.
[0050]
Then, the processing area of the surface of the wafer-ized sample 20 is scanned by the liquid metal ion

beam which converged. a liquid metal ion beam receives the surface of the wafer-ized sample 20 -- abbreviated -- since it glares so that it may become vertical, the surface can delete to **** the field where the liquid metal ion beam was irradiated, and the section 22 as eventually shown in drawing 4 (c) is obtained. The heights of the wafer-ized sample 20 will be shaved [both sides] by this section 22, and that thickness is about 0.1-0.5 micrometer.

[0051]

The tilt angle of the sample stage 5 is adjusted so that the gas ion beam which converged from the gas ion beam irradiation unit 7 may finally enter into an abbreviated perpendicular to the section 22, Etching removal of the damaged layer formed on the occasion of the cross section processing by the liquid metal ion beam on this TEM observation field by scanning the predetermined field (TEM observation field) of the section 22 by a gas ion beam is carried out. Same processing is performed also to the section of an opposite hand. The exposure of the gas ion beam to the section of an opposite hand can be performed by rotating 180 degrees of sample stages 5.

[0052]

In this example, the observation area is located in the center of the section 22, and does not adjoin the contact surface (the bottom and wall surface) contiguous to the section 22. Therefore, on the occasion of the etching removal of a damaged layer, like the case of the pickup mentioned above, the gas ion beam which converged is irradiated by only the observation area, and is not irradiated by the contact surface. For this reason, in a contact surface, discharge of the aggregated particle by the exposure of a gas ion beam like before is not produced. Therefore, the reattachment layer by the aggregated particle from a contact surface like before is not formed in the field of the observation area where the damaged layer was removed.

[0053]

Also in this example, if the spot size on the section of the gas ion beam which converged is set as bigger size (however, smaller than the section 22) like the case of the pickup mentioned above, a damaged layer is more removable in a short time.

[0054]

The removal of the damaged layer by the gas ion beam which converged in the taking-up method explained above or the production techniques of a TEM sample using a wafer-ized sample is applicable also to production of a SEM sample. In the case of a SEM sample, a section is formed by making a concave hole in the specified part of a wafer by a liquid metal ion beam, for example, and removal of a damaged layer is performed by scanning the predetermined field (field which carries out SEM observation) of the section by the gas ion beam which converged. When producing a SEM sample from a wafer-ized sample, a section is formed only in one side of a wafer-ized sample of a liquid metal ion beam, and removal of a damaged layer is performed by scanning the predetermined field (field which carries out SEM observation) of the section by the gas ion beam which converged.

[0055]

By the way, it is known on the occasion of the cross section processing by a liquid metal ion beam, and removal of the damaged layer by a gas ion beam that a stripe will arise in a section. as opposed to the sample which has unevenness on the surface -- a liquid metal ion beam -- the surface -- abbreviated -- since the working speed (etch rate) in the boundary (corner) of an uneven part and a flat portion differs when glaring from a vertical direction and performing cross section processing, the stripe according to surface

unevenness arises in the formed section. Also when the field (boundary) where construction material differs exists in a cross section processing field, the stripe by the difference in the working speed (etch rate) in these fields arises. Such a stripe bars the good section observation which used TEM and SEM.
[0056]
In the FIB device of this embodiment, by adopting either of the next procedures 1 and 2, the above stripes are removed and good section observation is realized.
[0057]
<Procedure 1>
(1-1) Irradiate a specimen surface with the liquid metal ion beam which converged from the 1st direction of radiation (for example, direction vertical to a specimen surface), and perform cross section processing. A stripe arises in the case of this cross section processing.
[0058]
(1-2) In order to remove a stripe, irradiate with and etch the liquid metal ion beam which converged to the section obtained by the above-mentioned cross section processing from the 2nd different direction of radiation from the 1st direction of radiation. Thereby, the stripe formed in the section is removed.
[0059]
(1-3) Irradiate with the gas ion beam which converged from the 3rd direction of radiation to the section where the stripe was removed, and remove the damaged layer on the observation area of a section. A stripe is formed by the removal process of this damaged layer.
[0060]
(1-4) In order to remove the stripe formed at the process of the above (1-3), irradiate with and etch the gas ion beam which converged to a section from the 4th different direction of radiation from the 3rd direction of radiation. Thereby, the stripe formed in the section is removed.
[0061]
The above-mentioned process of (1-1) and the process of (1-2) may be performed simultaneously. That is, it may be made to perform cross section processing, changing the 1st direction of radiation and 2nd direction of radiation. Similarly, the above-mentioned process of (1-3) and the process of (1-4) may also be performed simultaneously. In this case, a damaged layer will be removed, changing the 3rd direction of radiation and 4th direction of radiation.
[0062]
<Procedure 2>
(2-1) Irradiate a specimen surface with the liquid metal ion beam which converged from the 1st direction of radiation (for example, direction vertical to a specimen surface), and perform cross section processing. A stripe arises in the case of this cross section processing.
[0063]
(2-2) Irradiate with the gas ion beam which converged to the section obtained by the above-mentioned cross section processing from the 2nd different direction of radiation from the 1st direction of radiation, and remove the damaged layer on a section. A new stripe is formed in a section by the exposure of a gas ion beam although the stripe produced in (2-1) is removed in the removal process of this damaged layer.
[0064]
(2-3) ETCHIGU [the gas ion beam which converged / irradiate with and] from the 3rd different direction of

radiation from the 2nd direction of radiation to a section in order to remove the stripe formed at the process of the above (2-2). Thereby, the stripe formed in the section is removed.

[0065]

The above-mentioned process of (2-2) and the process of (2-3) may be performed simultaneously. That is, it may be made to remove a damaged layer, changing the 2nd direction of radiation and 3rd direction of radiation. In this case, the stripe produced at the time of cross section processing and the stripe produced in the case of damaged layer removal will be removed simultaneously.

[0066]

The change of the direction of radiation in above-mentioned Procedure 1 and Procedure 2 can be performed by controlling the tilt angle of a sample stage.

[0067]

The FIB device explained above is an example, and an equipment configuration and a processing procedure are not limited to what was illustrated, and can be changed suitably. For example, it is also possible to build a device, a manipulator, etc. for observation of SEM, TEM, etc. into a FIB device.

[0068]

The outline composition of the complex device which included the function in which the section observation by SEM is possible in the FIB device shown in drawing 1 at drawing 5 is shown. In the composition shown in drawing 1, this complex device adds the electron beam irradiation equipment 30 which scans the section formed in the sample 6 with an electron beam, and the secondary electron detector 31 which detects the secondary electron from the section produced by the scan of that electron beam.

[0069]

When carrying out SEM observation of the section formed in the specific site of the sample 6, the tilt angle of the sample stage 5 is controlled so that the electron beam from the electron beam irradiation equipment 30 enters at an angle of predetermined to the section. And a section is scanned with an electron beam and the secondary electron detector 8 detects the secondary electron emitted by this scan from a section. A SEM image is acquired based on the output of this secondary electron detector 8.

[0070]

In the ion beam equipment of this invention explained above, although 10 kV is common from the number 10V as for the accelerating voltage of a gas ion beam, it is so good that it is low in order to lessen a damage. However, since an etch rate will become slow if low accelerating voltage is used, it is desirable to set up the accelerating voltage which etching ends in practical time.

[0071]

moreover -- the gas ion beam which converged receives a section -- abbreviated -- although it enters vertically or aslant, this invention is not limited to this. For example, if it is a case where irradiated with the liquid metal ion beam from the normal line direction to the surface of a sample, and cross section processing is performed, It is also possible to carry out etching removal of the damaged layer on the predetermined field (a TEM observation field or a SEM observation area) of a section, as it irradiates with the gas ion beam which converged from the same normal line direction. in this case, since a part of gas ion beam is irradiated by the contact surface (bottom), an aggregated particle is emitted in a contact surface, but that burst size is markedly boiled compared with the burst size in the former, and there is. [few] Therefore, even if a reattachment layer is formed in the portion from which the damaged layer was removed, the quantity

(thickness) comes out very only, and, for a certain reason, section observation is not barred greatly.

[0072]

[Effect of the Invention]

Since the reattachment layer of the aggregated particle from a contact surface is not formed in an observed face (section) according to this invention when removing a damaged layer as explained above, There is an effect that good section observation in SEM or TEM can be performed and that a TEM sample and a SEM sample can be provided.

[Brief Description of the Drawings]

[Drawing 1]It is a block diagram showing the main composition of the FIB device which is one embodiment of this invention.

[Drawing 2]It is a mimetic diagram showing the exposure of the section by a gas ion beam.

[Drawing 3](a) - (c) is a mimetic diagram showing the removal process of the damaged layer by the gas ion beam which converged.

[Drawing 4](a) - (c) is a mimetic diagram showing the production processes of the TEM sample from a wafer-ized sample.

[Drawing 5]It is a block diagram showing the outline composition of the complex device incorporating a SEM function in the FIB device shown in drawing 1.

[Drawing 6]It is a mimetic diagram showing the outline composition of the conventional FIB device.

[Drawing 7](a) And (b) is a mimetic diagram for explaining production of the TEM sample by the taking-up method.

[Drawing 8](a) And (b) is a mimetic diagram for explaining extraction of the TEM sample by the taking-up method.

[Drawing 9]The sectional view of the portion of the TEM sample which shows drawing 7 (b) (a), and (b) are the elements on larger scale of (a).

[Drawing 10]It is a mimetic diagram showing the outline composition of the FIB device indicated to JP,6-260129,A.

[Drawing 11](a) - (c) is a mimetic diagram showing the morphosis of a reattachment layer.

[Description of Notations]

1 Liquid metal ion-beam-irradiation device

2 Secondary charged particle detector

3 Tear gas gun

4 Sample electrode holder

5 Sample stage

6 Sample

6a and 22 Section

6b Observation area

6c Contact surface

7 Gas ion beam irradiation unit

7a Gas ion beam spot

8 Slitting

10 and 21 Deposition film

11 Damaged layer
20 Wafer-ized sample
30 Electron beam irradiation equipment
31 Secondary electron detector

[Translation done.]

CLAIMS

[Claim(s)]
[Claim 1]
A liquid metal ion-beam-irradiation means to irradiate a specific site of a sample with a predetermined liquid metal ion beam, and to form a section in it,
Ion beam equipment scanning a predetermined field of said section by a gas ion beam which converged on a predetermined beam diameter, and having a gas ion beam irradiation means which removes a damaged layer on a field predetermined [this].
[Claim 2]
The ion beam equipment according to claim 1 with which a size of the beam spot on said section of said gas ion beam is characterized by being smaller than a size of said section.
[Claim 3]
The ion beam equipment according to claim 1 with which a size of the beam spot on said section of said gas ion beam is characterized by being smaller than said predetermined area size.
[Claim 4]
as for said gas ion beam irradiation means, said gas ion beam receives said section -- abbreviated -- ion beam equipment given in any 1 paragraph of claims 1 thru/or 3 constituting so that it may enter vertically or aslant.
[Claim 5]
Ion beam equipment given in any 1 paragraph of claims 1 thru/or 4, wherein said gas ion beam is an inert-gas-ion beam.
[Claim 6]
Ion beam equipment given in any 1 paragraph of claims 1 thru/or 5 scanning said predetermined field with an electron beam, and having further an electron microscope means to form a transmission electron image or a secondary electron image of a field predetermined [this].
[Claim 7]
The 1st process of irradiating a specific site of a sample with a predetermined liquid metal ion beam, and forming a section in it,

An ion beam machining method scanning a predetermined field of said section by a gas ion beam which converged on a predetermined beam diameter, and having the 2nd process of removing a damaged layer on a field predetermined [this].

[Claim 8]

An ion beam machining method according to claim 7, wherein said 2nd process includes a process of changing the degree of incidence angle to said section of said gas ion beam, and removing said damaged layer.

[Claim 9]

An ion beam machining method according to claim 7 or 8, wherein said 1st process includes a process of changing irradiation angles of said predetermined liquid metal ion beam, and forming said section.

[Claim 10]

An ion beam machining method given in any 1 paragraph of claims 7 thru/or 9 to which a size of the beam spot on said section of said gas ion beam is characterized by being smaller than a size of said section.

[Claim 11]

An ion beam machining method given in any 1 paragraph of claims 7 thru/or 9 to which a size of the beam spot on said section of said gas ion beam is characterized by being smaller than said predetermined area size.

[Claim 12]

An ion beam machining method given in any 1 paragraph of claims 7 thru/or 11, wherein said gas ion beam is an inert-gas-ion beam.

[Translation done.]